<Solid State Chemistry> Quantum Spin Fluids

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- Quantum Spin Fluids -

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Scope of Research

Quantum spin oxide systems such as high-T_c superconducting cuprates, $La_{2-x}(Ba,Sr)_xCuO_4$, $Nd_{2-x}Ce_xCuO_4$ and $Pr_{2-x}LaCe_xCuO_4$ are synthesized in the form of single crystals using traveling-solvent-floating-zone method. Detailed equilibrium phase diagram of Pr_6O_{11}-La_2O_3-CuO system is also investigated to elucidate the effect of oxygen nonstoichiometry on these oxide. Main subjects and techniques are: mechanism of high-T_c superconductivity: origin of quantum phase separation in strongly correlated electron systems: spin excitations in quantum spin systems: interplay between spin and charge flow in doped spin system: neutron scattering by using triple-axis as well as time-of flight techniques.

Research Activities (Year 2002)

Presentations

A comparative study on the magnetic order in hole- and electron-doped cuprates, K. Yamada, M. Fujita, T. Uefuji, H. Goka, M. Matsuda, I. Watanabe, K. Nagamine, The 23th International Conference on Low Temperature Physics, Hiroshima, Japan, 26 Aug. 2002.

Magnetic excitation in the spin-glass phase of $La_{2-x}Sr_xCuO_4$, H. Goka, S. Kuroshima, M. Fujita, K. Yamada, The 23th International Conference on Low Temperature Physics, Hiroshima, Japan, 26 Aug. 2002.

Doping effect on magnetic order and superconductivity in electron-doped cuprate single crystals $Nd_{2-x}Ce_xCuO_4$, T. Uefuji, T. Kubo, S. Kuroshima, M. Fujita, K. Yamada, M. Matsuda, I. Watanabe, K. Nagamine, CREST International Workshop on Novel Quantum Phenomena in Transition Metal Compound, Sendai, Japan, 30 Aug. 2002.

Phases and their relations in the Pr_6O_{11}-La_2O_3-CuO system, Y. Ikeda, K. Yamada, Y. Kusano, J. Takada, 10th International Ceramic Congress & 3rd Forum on New Materials, Florence, Italy, 16 July 2002.

Spin dynamics of pure and diluted S=1/2 Kagome-like magnetic system $(Cu_xZn_{1-x})_3V_2O_7(OH)_22H_2O$, A. Fukaya, Y. Fudamyo, I.M. Gat, T. Ito, M. Larkin, A.T. Savici, Y.J. Uemura, P.P. Kyriaku, G.M. Luke, M.T.Rovers, K.M.Kojima, A. Keren, M. Hanawa, Z. Hiroi, 9th International Conference on Muon spin rotation/relaxation/resonance, Williamsburg, VA, USA, 4 Jun. 2002.

Grants

Yamada K, Study of quantum phase separation in the transition metal oxides, Grant-in-Aid for Scientific Research on Priority Areas (Novel Quantum Phenomera in Transition Metal Oxides), 1 April 2000 - 31 March 2003.

Yamada K, Study of X-ray inelastic scattering study on the charge and lattice dynamics in metal oxides, Grant-in-Aid for Scientific Research (B), 1 April 2002 - 31 March 2004.

Fujita M, Study of High-T_c superdonductivity mechanism in the electron-doped cuprates, Grant-in-Aid for Encouragement of Yong Scientists, 1 April 2001 - 31 March 2003.

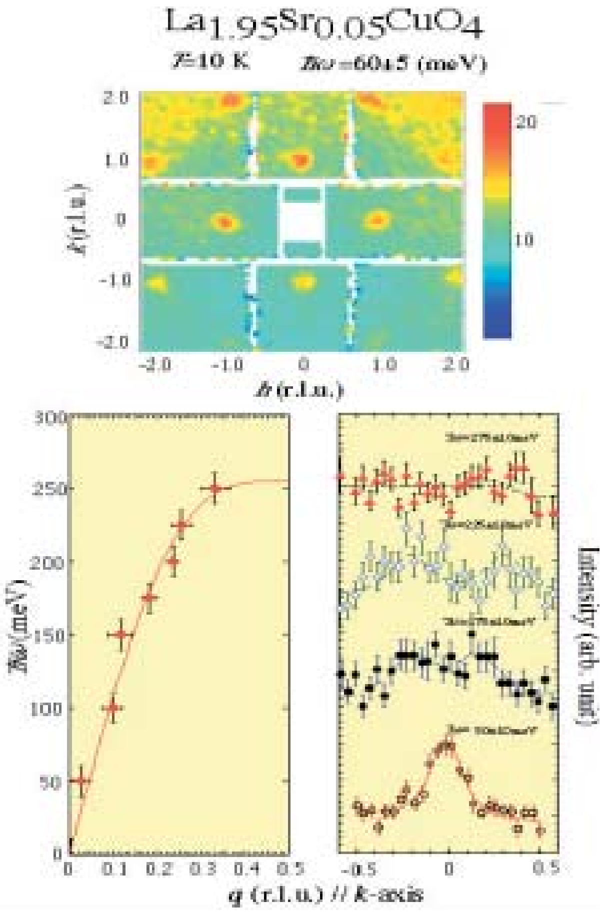
Yamada K, Collaboratory on Electron Correlations-Toward a New Research Network between Physics and Chemistry, Grant-in-Aid for Creative Scientific Research, 1 April 2001 - 31 march 2006.

Magnetic excitation in spin-glass phase of $La_{2-x}Sr_xCuO_4$

Magnetic excitation in the spin glass phase of $La_{2-x}Sr_xCuO_4$ (x=0.05) which is located near the lower critical concentration of high-T_c superconductivity was observed up to 300 *meV* by pulsed neutron scattering experiment. The upper figure is a contour map showing the square lattice of inelastic magnetic peaks at ω=60 *meV* and T=10 K.

In the energy region below ~50 *meV*, the magnetic peak width decreases with increasing energy. On the other hand, over ~50 *meV*, it increases with energy, and we can draw a similar dispersion curve as observed in La_2CuO_4 (lower figure). The nearest neighbor interaction J was evaluated to be 108±6 *meV* which is slightly smaller than that of La_2CuO_4 by applying the 2D antiferromagnetic dispersion relation.

The imaginary part of dynamical magnetic susceptibility χ"(ω) decreases monotonically up to ~50 *meV* with energy and become almost energy-independent in the energy region of >50 *meV* like La_2CuO_4. The above-mentioned features indicate that it is possible that the spin fluctuation in the low energy region (<50 *meV*) crosses over to that of spin wave-like.



Upper panel: A contour map of intensity of scattered neutron. Spots making square lattice are magnetic excitations. Lower panel: The energy dependence of magnetic excitation (right) and the dipersion deviated from these data (left).

Reversible precipitation and resolution phenomenon in $Pr_{2-x}La_xCuO_4$ (1.35<x<1.5)

Solid-solubility range and phase stability of $Pr_{2-x}La_xCuO_4$(0<x<2) have been studied mainly from high temperature X-ray diffraction, thermogravimetric analysis (TGA), differential thermal analysis (DTA), and TEM observation. There are two tetragonal T'-type solid solutions with slightly different lattice constants in Pr_2CuO_4-La_2CuO_4 system. We observed an interesting phenomenon in $Pr_{2-x}La_xCuO_4$ (1.35<x<1.5)(T'_B) as shown schematically in Fig. 1. High temperature X-ray diffraction mesurement of T'_B phase reveals phase segregation into three phases (T'_B-, T-type, and unknown phase) upon heating process at around 900°C in O_2. Surprisingly, in the cooling process, reformation into original T'_B phase occurred at around 200°C. At the same time, a sintered pellet transforms into fine powder (~10μm) in a few ten seconds. This reaction occured completely reversible upon cyclic heat treatment. Reversibility of the phenomenon was also confirmed by TGA and DTA measurement. To our best of knowledge, these phenomena have not been reported in high-T_c superconductor related cuprates.

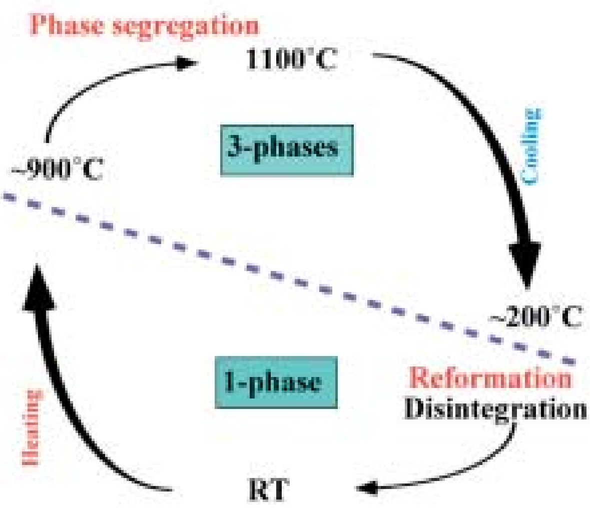


Figure 1. A schematic representation of a reversible phase change for T'_B phase.